HUC 10290108 – South Grand
Water body ID: 1249
303(d) Listing: *Escherichia coli*

Total Maximum Daily Load
Implementation Strategies
for the
South Grand River Watershed
Cass and Henry Counties

Pollutant: *Escherichia coli*

Prepared by: Water Protection Program, Watershed Protection Section

WATER BODY SUMMARY
Total Maximum Daily Loads (TMDL) for South Grand River
303(d) Listing: *Escherichia coli (E. coli)* Bacteria

Water body **TMDL Development Priority**
South Grand River High

Location: Cass and Henry Counties

8-digit Hydrologic Unit Code (HUC):[1]
10290108 – South Grand

12-digit HUC Subwatersheds:
See Section 2

Water Body Identifications (WBIDs) and Hydrologic Class:[2]
1249 - Class P

Designated Uses:[3]
Irrigation
Livestock and wildlife protection
Human health protection
Warm water habitat (aquatic life)
Whole body contact recreation category B
Secondary contact recreation

Impaired Use:
Whole body contact recreation category B

Pollutant Identified on the 2018 303(d) List:
Escherichia coli (E. coli) (fecal indicator bacteria)

Identified Sources on the 2018 303(d) List:
Rural nonpoint sources

Length and Location of Impaired Segments:
South Grand River (WBID 1249): 66.8 miles, from mouth to Section 02, Township 44N, Range 33W

---

[1] Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 2,270 8-digit hydrologic units (USGS 2019). A hydrologic unit is a drainage area delineated to nest in a multilevel, hierarchical drainage system. A hydrologic unit code is the numerical identifier of a specific hydrologic unit consisting of a 2-digit sequence for each specific level within the delineation hierarchy (FGDC 2003).

[2] For hydrologic classes see 10 CSR 20-7.031(1)(F). Class P streams maintain permanent flow even in drought periods.

[3] For designated uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H. Presumed uses are assigned per 10 CSR 20-7.031(2)(A) and (B) and are reflected in the Missouri Use Designation Dataset described at 10 CSR 20-7.031(2)(E).

TABLE OF CONTENTS

Figures

Tables

1. Introduction

A total maximum daily load (TMDL) report for South Grand River addresses elevated *Escherichia coli* (*E. coli*) bacteria concentrations that resulted in the water body's placement on Missouri's 303(d) List of Impaired Waters. The TMDL established for the impaired water bodies represent the *E. coli* loading capacity for each stream, which is the maximum amount of a pollutant that a water body can assimilate and still attain and maintain water quality standards. Watershed characteristics and *E. coli* loading targets can be found in the TMDL report, which is available on the Missouri Department of Natural Resources' website at dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/tmdls. Questions regarding the TMDLs may be sent via email to tmdl@dnr.mo.gov or by calling the Department's Watershed Protection Section at 573-751-5723.

This implementation strategies document is a companion to the TMDL reports and suggests actions that will reduce pollutant loading in order to meet the loading capacities established in the TMDL document. The goal of the TMDLs is to attain and maintain designated uses in the water bodies. The whole body contact recreation category B use is impaired in South Grand River due to elevated *E. coli* concentrations in the river. Although this implementation document is drafted primarily to implement the goals of the *E.coli* TMDL, this document also addresses nutrient loading. Many of the practices suggested in this document will reduce both *E. coli* and nutrient loading.

This document neither prescribes nor prohibits any specific practices or technologies for reducing pollutant loading in the impaired water body and is not intended to serve as the sole means of remediation and restoration. However, the Department recognizes that technical guidance and support are critical to achieving the goals of any TMDL. Therefore, while the TMDL calculates the maximum pollutant loading that the impaired water body can assimilate and still attain and maintain water quality standards, this strategies document provides additional information to assist in meeting the TMDL loading goals including: pollutant reduction strategies, example calculations of pollutant reductions, potential participants in the watershed, and funding sources. Because the TMDL addresses pollutant loading from all potential sources in the watershed, this strategies document provides guidance for meeting the loading targets assigned to both point and nonpoint sources.[4]

Point source pollutant loading controls are implemented primarily through the Missouri State Operating Permit program.[5] Effluent limits are established in facility permits based on the assumptions and requirements of the wasteload allocations and other recommendations in the TMDL documents. Cost-share loans are available from the State Revolving Fund and are administered through the Department's Financial Assistance Center to help finance facility upgrades that are necessary to meet more stringent effluent limits.

Watershed management practices that reduce nonpoint source pollutant loading are conducted voluntarily by interested stakeholders and landowners within the watersheds. In accordance with Section 319 of the federal Clean Water Act, the U.S. Environmental Protection Agency (EPA) provides funding for nonpoint source pollutant load reduction practices. Section 319 nonpoint source

[4] Point and nonpoint sources are defined and discussed in Sections 5.1 and 5.2 of the TMDL report for South Grand River.

[5] The Missouri State Operating system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program. The NPDES program requires all point sources that discharge pollutants to waters of the United States to obtain a permit. Issued and proposed operating permits are available online at dnr.mo.gov/water/business-industry-other-entities/permits-certification-engineering-fees/wastewater.

subgrants are administered through Missouri's Section 319 program to assist organizations with watershed planning or implementation of activities as described in a Nine Element Watershed Management Plan (or alternative plan under certain specific conditions) that has been accepted by the Department and EPA. The Nine Key Elements of a Watershed Management Plan are provided in Appendix A. More information on Missouri's Section 319 subgrant program is available at: dnr.mo.gov/water/what-were-doing/nonpoint-source-pollution-section-319. Interested parties may also contact the Section 319 subgrant program directly at MoDNR.NPSprogram@dnr.mo.gov or 573-751-4932. Local communities and citizens looking to develop watershed plans to improve water quality are also encouraged to contact the University of Missouri Extension at 573-882-0085. Information regarding the University Extension's soil and water program is available online at extension.missouri.edu/find-your-interest/agriculture-and-environment/agricultural-systems-and-natural-resources/soil-and-water. Additional cooperating organizations and sources of funding are provided in Section 11 of this document.

2. Watershed Characteristics

South Grand River water body identification (WBID) 1249 is located in west Missouri south of the Kansas City area within the South Grand subbasin, which is cataloged by the U.S. Geological Survey (USGS) as the 8-digit hydrologic unit code (HUC) 10290108. South Grand River is formed by the confluence of Massey Creek and East Creek approximately five miles southwest of Peculiar, Missouri. The river flows southeast for 66.8 miles and enters Harry S. Truman Reservoir near Clinton, Missouri. The South Grand River watershed is comprised of 32, 12-digit HUC subwatersheds totaling 1,316 square miles as displayed in Figure 1 and listed in Table 1.

The South Grand River watershed is located in the Wooded Osage Plains EPA Level IV ecoregion. The Wooded Osage Plains ecoregion is an undulating plain with smooth, low, limestone escarpments and small areas of exposed bedrock (Chapman et al. 2002). Underlying geology consists of alternating beds of limestone, sandstone, shale, and coal. The sandstone and shale impede downward water movement, which results in few aquifers and streams that are surface water dominated. Most streams are ephemeral or intermittent. Stream channels are highly meandering with very low gradients. Waters are generally turbid, and stream beds are dominated by sand and silt with few poorly defined riffles (MoRAP 2005).

Land cover types present in the South Grand River watershed are summarized in Table 2. Figure 2 depicts the distribution of the land cover types throughout the watershed. Seventy-two percent of the watershed is covered by agricultural areas including cultivated cropland and pasture areas potentially used for livestock grazing.

Figure 1. Location of the South Grand River Watershed

Table 1. 12-digit HUC Subwatersheds within the South Grand 8-digit HUC (10290108)

Last 4 Digits	Name	Last 4 Digits	Name
0101	East Creek	0307	Headwaters Camp Branch
0102	Massey Creek	0308	Camp Branch
0103	Poney Creek	0309	Lost Creek-Big Creek
0104	South Fork South Grand River	0401	Bear Creek
0105	Adams Branch-South Grand River	0402	Panther Creek-Big Creek
0201	Headwaters East Branch South Grand River	0403	Norris Creek-Big Creek
0202	East Branch South Grand River	0404	Honey Creek
0203	Black Creek-South Grand River	0405	Big Creek
0204	Morman Fork	0501	Big Deer Creek-South Grand River
0205	Eightmile Creek-South Grand River	0502	Sugar Creek-South Grand River
0301	Middle Big Creek	0503	Elk Fork-South Grand River
0302	Headwaters Big Creek	0504	Knob Creek
0303	East Branch Crawford Creek	0505	Cove Creek-South Grand River
0304	West Branch Crawford Creek	0506	White Oak Creek-South Grand River
0305	Crawford Creek	0701	Fields Creek-South Grand River
0306	Duncan Branch-Big Creek	0702	Town Creek-South Grand River

Table 2. Land Cover in the South Grand River Watershed

Land Cover Type	Area Square miles	Percent
Developed, High Intensity	1.7	0.13%
Developed, Medium Intensity	6.5	0.50%
Developed, Low Intensity	34.1	2.59%
Developed, Open Space	54.9	4.17%
Barren Land	2.4	0.18%
Cultivated Crops	334.7	25.43%
Hay/Pasture	614.1	46.66%
Forest	178.1	13.53%
Shrub and Herbaceous	5.4	0.41%
Wetlands	67.7	5.14%
Open Water	16.5	1.25%
Total	1,316	100%

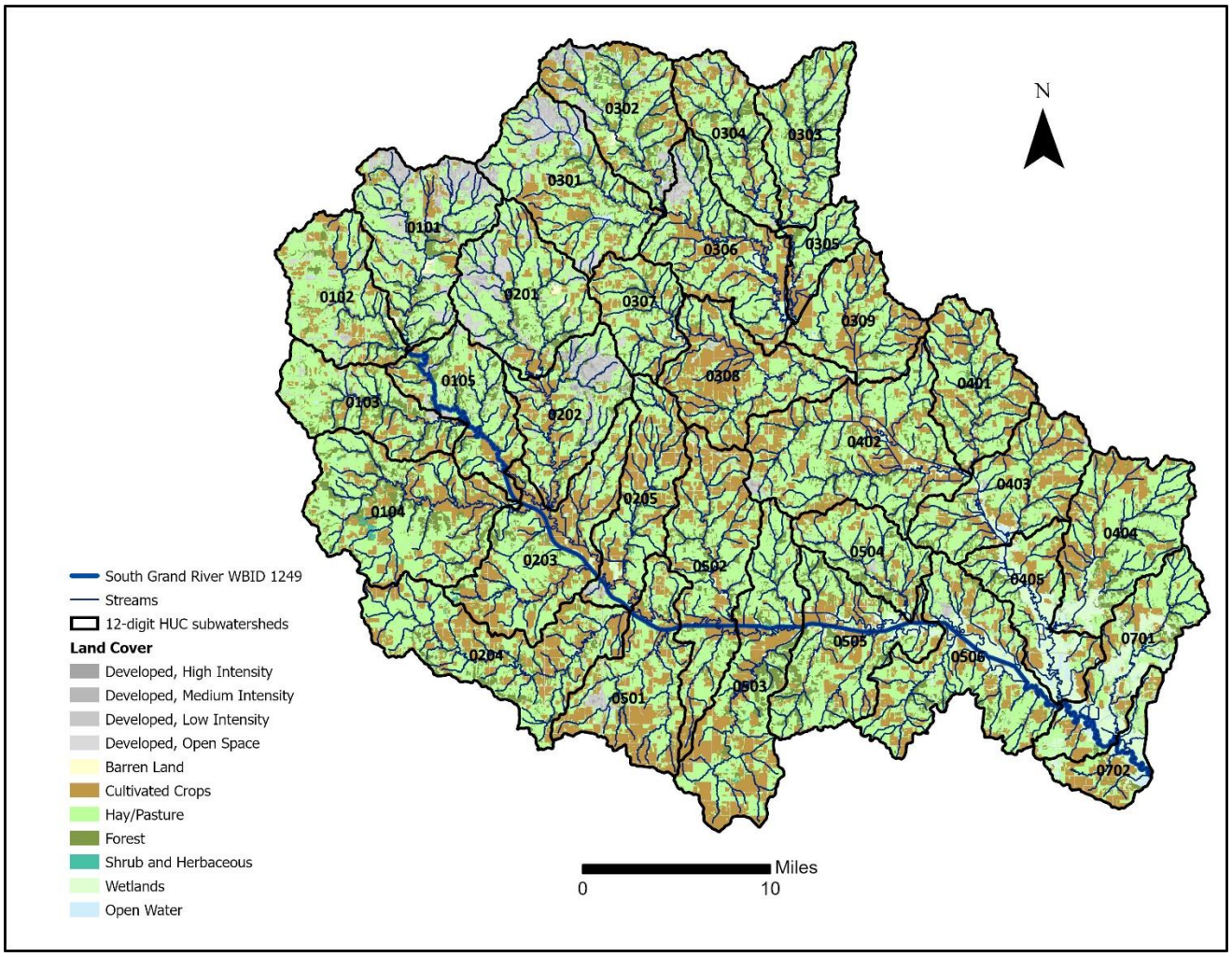

Figure 2. Land Cover in the South Grand River Watershed

3. Water Quality Impairments

Water quality criteria are limits on certain chemicals or conditions in a water body established to protect designated uses. The whole body contact recreation category B designated use is impaired due to high *E. coli* bacteria concentrations in South Grand River. Whole body contact recreation includes activities that involve direct human contact with waters of the state to the point of complete body submergence (10 CFR 20-7.031(1)(C)2.A.). During such activities, such as swimming, accidental ingestion of the water may occur and there is direct contact to sensitive body organs, such as the eyes, ears, and nose. Whole body contact category A applies to waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreation uses by the public (10 CSR 20-7.031(1)(C)2.A.(I)). Whole body contact category B applies to waters designated for whole body contact recreation not contained within category A (10 CSR 20-7.031(1)(C)2.A.(II)). Secondary contact recreation, which includes activities such as boating, fishing, and wading, are activities that may result in contact with the water that is either incidental or accidental and the probability of ingesting appreciable quantities of water is minimal (10 CSR 20-7.031(1)(C)2.B.). The secondary contact recreation uses are not impaired in South Grand River.

E. coli are bacteria found in the intestines of humans and warm-blooded animals and are used as indicators of potential fecal contamination and risk of pathogen-induced illness to humans. In accordance with Missouri's 2020 Listing Methodology Document, the whole body contact recreation category B designated uses for South Grand River are impaired because the geometric means of *E. coli* samples collected during the recreational season were greater than 206 colony forming units (cfu) per 100 milliliters (mL) in the most recent three years having available data with five or more samples.[6] Sufficient data consistent with the assessment methodology are available to support these listings as summarized in Table 2. As shown, *E. coli* concentrations exceeded the geometric mean of 206 cfu/100 mL during the recreational season in 1999, 2001, and 2007 when at least five samples were collected. *E. coli* data are collected by the U.S. Geological Survey and are available for each year between 2008 and 2020, however, fewer than five samples were collected in those years.

Table 3. Summary of Recreational Season *E. coli* Data for South Grand River

Recreational Season	Number of Samples	Minimum (cfu/100 mL)	Maximum (cfu/100 mL)	Geometric Mean (cfu/100 mL)
1999	6	46	5,500	207.12
2001	7	1	29,000	223.88
2007	5	43	15,000	307.03

4. Causes and Sources of Pollutant Loads

Section 5 of the South Grand River *E. coli* TMDL provides an inventory and assessment of all known and suspected sources of bacteria loading in the South Grand River watershed. The bacteria sources identified in the TMDL are based on issued permits and a general knowledge of watershed conditions. For some sources, specific loading contributions remain unknown. Groups interested in

[6]Missouri's 2020 Listing Methodology Document is available online at dnr.mo.gov/document/methodology-development-2020-section-303d-list-missouri

implementing best management practices (BMPs) in the watershed may want to consider employing microbial source tracking techniques to better identify the primary sources of *E. coli* in their area (i.e., humans, poultry, equine, cattle, domestic pets, or wildlife). However, such techniques can be cost-prohibitive and may be unnecessary if localized land use activities are already well known. More information regarding microbial source tracking techniques is available online from the USGS at water.usgs.gov/owq/microbial.html.

4.1 Agricultural Lands

Croplands, pasturelands, and low-density animal feeding operations are potential sources of bacteria in surface waters. Bacteria are transported in runoff from areas fertilized with animal manure and where livestock are present. Runoff can result from precipitation or excessive irrigation. Section 640.760 Revised Statutes of Missouri (RSMo) establishes setback distances for surface application of liquefied manure from a confined animal feeding operation (CAFO) by a third party.[7] Pursuant to Section 640.760 RSMo, the Department may enforce stricter setbacks. Soil and Water Conservation Districts provide funding and guidance for the development of nutrient management plans for private lands. Areas where nutrient management plans guide manure application and where best management practices are used to reduce soil erosion contribute less bacteria to surface waters than unmanaged areas. Although grazing areas are typically well vegetated, livestock tend to congregate near feeding and watering areas and create barren areas that are susceptible to erosion (Sutton 1990). Livestock that are not excluded from streams deposit manure and thus bacteria directly into waterways. As shown previously in Table 1 and Figure 2, 72 percent of the watershed is covered by agricultural areas.

4.2 Riparian Corridor Conditions

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the attenuation of pollutants in runoff. Land cover within 100 feet of streams in the South Grand River watershed is presented in Table 3. Agricultural areas constitute over 33 percent of the riparian corridors of streams in the South Grand River watershed. These areas may be more susceptible to *E. coli* loading. Forty percent of the riparian corridor area is forested. This indicates that some *E. coli* transported from adjacent cropland and pasture lands into those areas may be intercepted before it enters the streams.

Table 4. Land Cover in the Riparian Corridors of South Grand River and Tributaries

Land Cover Type	Riparian Corridor Land Cover Type Area	
	Acres	Percent
Developed, High Intensity	0.03	0.04%
Developed, Medium Intensity	0.15	0.17%
Developed, Low Intensity	1.20	1.38%
Developed, Open Space	2.43	2.80%
Barren Land	0.07	0.09%
Cultivated Crops	8.02	9.23%

[7] Section 640.760 RSMo setback distances are: 50 feet from a property boundary, 300 feet from any public drinking water lake, 300 feet from any public drinking water intake structure, 100 feet from any perennial and intermittent streams without vegetation abutting such streams, and 35 feet from any perennial and intermittent streams with vegetation abutting such streams.

Land Cover Type	Riparian Corridor Land Cover Type Area	
	Acres	Percent
Hay/Pasture	21.25	24.46%
Forest	34.77	40.02%
Shrub and Herbaceous	0.46	0.53%
Wetlands	15.85	18.24%
Open Water	2.65	3.05%
Total:	86.89	100.00%

4.3 Onsite Wastewater Treatment Systems

Properly functioning onsite residential wastewater treatment (septic) systems should not contribute significant amounts of *E. coli* to surface waters. Failing systems, however, may be sources of bacteria during wet or dry weather. Proper maintenance of onsite residential wastewater treatment systems including septic tanks, associated drain fields, and household lagoons will minimize bacteria loading to surface waters.

5. Existing Loads and Needed Reductions

The existing loads are based on the *E. coli* TMDL and nitrogen and phosphorus load duration curves developed using the EPA Region 7 Regional Technical Assistance Group (RTAG) benchmark values. The reduction estimates provided do not differentiate between point source loading and nonpoint source loading. However, assumptions regarding specific sources in the watershed and the flow conditions under which they are likely to contribute loading can inform watershed planning. For example in South Grand River, bacteria reductions are needed during moist and high flow conditions, therefore BMPs that address stormwater runoff will address the most significant sources of pollutant loading to the river. Additional water quality monitoring conducted during watershed planning may help determine specific areas, or "hot spots," where significant loading is occurring and where BMPs may be the most effective. Additionally, as discussed in Section 4, microbial source tracking methods may also help groups identify and address specific sources. Groups wishing to develop a monitoring component to any localized watershed plan are encouraged to consult with the Department's Water Quality Monitoring and Assessment Unit, available at 573-522-4505.

5.1 *E. coli* Bacteria

As mentioned previously, the whole body contact recreation category B designated use is impaired due to high *E. coli* bacteria concentrations in South Grand River. The *E. coli* TMDL for South Grand River is represented by a load duration curve that quantifies the loading capacity at all possible flows. Table 4 summarizes the TMDL at selected flows and the load reductions that are needed to meet the TMDL displayed in Section 7 of the TMDL document. The load reductions were calculated based on the geometric mean of observed *E. coli* data recorded during each selected flow condition. As shown, *E. coli* concentrations do not exceed water quality criterion during low flow to mid-range conditions.

Table 5. South Grand River TMDLs and Needed Reductions

Percent of Time Flow Is Equal Exceeded	Flow Condition	Median Flow (cfs)	TMDL (counts/day)	Existing Load (count/day)	Needed Reduction (counts/day)	Needed Reduction (%)
100-90	Low flow	6.52	7.13E+10	2.13E+10	0.00E+00	0.00%
90-60	Dry Conditions	47.61	2.40E+11	1.10E+11	0.00E+00	0.00%
60-40	Mid-Range	197.10	9.93E+11	9.55E+11	0.00E+00	0.00%
40-10	Moist Conditions	706.07	3.56E+12	1.33E+13	9.73E+12	73.23%
10-0	High Flow	5,767.85	2.91E+13	2.32E+14	2.03E+14	87.48%

5.2 Nitrogen and Phosphorus

Missouri's water quality standards do not establish nutrient criteria for streams. However, nutrient load reductions are a statewide priority, and many of the nonpoint source management measures that reduce *E. coli* loading also reduce nitrogen and phosphorus loading. Excessive nitrogen and phosphorus loading can lower the quality of ground and surface water. In high quantities, nitrogen has the potential to harm animals and humans. Phosphorus leachate or runoff attached to sediment particles entering the surface water contributes to excessive algae growth causing low oxygen levels in surface water that impairs aquatic life and contributes to bad tasting drinking water (NRCS 2013).

Nutrient targets used for load duration curves are based on RTAG benchmark values. These benchmark values are expected to be protective of Missouri's designated uses, but are not water quality criteria codified in Missouri's Water Quality Standards regulations at 10 CSR 20-7.031. In the absence of Missouri specific nutrient criteria for streams, these targets are provided only as guidance to assist watershed planning activities. South Grand River is not currently identified as impaired due to nutrients and no specific nutrient reduction is required for attainment of existing applicable water quality standards. Groups developing their own watershed plans may determine that alternative, scientifically defensible, nutrient targets are more appropriate for South Grand River. If a TMDL is developed in the future to address nutrient pollution in South Grand River, then the load allocations established in that approved TMDL should serve as the targets for watershed planning and nonpoint source nutrient reduction efforts.

Tables 5 and 6 summarize the nitrogen and phosphorous loads at selected flows. The load reductions were calculated based on the 95th percentile of observed total nitrogen and total phosphorous that exceeded the RTAG recommendation of 0.9 milligram per liter (mg/L) of total nitrogen and 0.075 mg/L total phosphorous. The data were collected by USGS in South Grand River near Archie, MO from 2007 to 2021.

Table 6. Total Phosphorous Loads and Recommended Reductions

Percent of Time Flow Is Equal or Exceeded	Flow Condition	Median Flow (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Reduction (lbs/day)	Needed Reduction (%)
100-90	Low flow	6.52	2.64	69.01	66.37	96.17%
90-60	Dry Conditions	47.61	19.26	196.70	177.43	90.21%
60-40	Mid Range	197.10	79.75	422.97	343.22	81.15%
40-10	Moist Conditions	706.07	285.69	2,227.60	1,941.91	87.17%
10-0	High Flow	5,767.85	2,333.82	22,510.98	20,177.17	89.63%

Table 7. Total Nitrogen Loads and Recommended Reductions

Percent of Time Flow Is Equal or Exceeded	Flow Condition	Median Flow (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Reduction (lbs/day)	Needed Reduction (%)
100-90	Low flow	6.52	31.68	255.52	223.84	87.60%
90-60	Dry Conditions	47.61	231.17	1192.10	960.93	80.61%
60-40	Mid Range	197.10	957.00	3669.56	2712.56	73.92%
40-10	Moist Conditions	706.07	3428.30	22,143.39	18,715.09	84.52%
10-0	High Flow	5,767.85	2,8005.80	285,965.65	257,959.86	90.21%

6. Point Source Implementation

Federal regulations at 40 CFR 122.44(d)(1)(vii)(B) require permit conditions to be consistent with the assumptions and requirements of TMDL wasteload allocations and other recommendations in the TMDL documents. How these conditions are expressed can vary depending upon the pollutant and nature of the discharge. Although TMDLs are required to be written for daily time increments, permit effluent limits may be written in a form that derives from and complies with applicable water quality standards that use any time measure (40 CFR 122.44(d)(1)(vii)(A) and EPA 2006). The Department's permit writers have discretion for how TMDL wasteload allocations are expressed in a permit and for determining appropriate implementation schedules. Permit writers should consult available permit writing handbooks and technical support documents to determine appropriate limits.[8] Although wasteload allocations are often specified for individual facilities, in some cases, it may be appropriate for pollutant loadings to be shifted between the individual facilities during permitting as long as the sum of the wasteload allocations remains unchanged and the loading capacity is not exceeded. In no case does a TMDL wasteload allocation allow for permit limits that exceed water quality standards. If water quality standard revisions result in criteria more stringent than an established TMDL wasteload allocation, then the more stringent criteria should be used in deriving the permit limits.[9] Information regarding the Department's permitting process is available online at dnr.mo.gov/water/business-

[8] The Department maintains a Water Pollution Control Permit Manual to provide guidance to permit writing staff and is available online at dnr.mo.gov/water/business-industry-other-entities/technical-assistance-guidance/wastewater-permit-writers-manual. Additionally the EPA maintains a National Pollutant Discharge Elimination System (NPDES) Permit Writers' Manual online at epa.gov/npdes/npdes-permit-writers-manual .

[9] Federal regulations at 40 CFR 131.21, also known as the "Alaska Rule," require water quality standards to be approved by the EPA before they can be used for Clean Water Act purposes (i.e., water quality-based effluent limitations or TMDLs).

industry-other-entities/permits-certification-engineering-fees/wastewater or by calling the Department's Operating Permit Section at 573-522-4502.

Table 7 lists the types of point sources in the South Grand River watershed that should be addressed in order to achieve the TMDL wasteload allocation targets. As noted in the TMDL, 16 municipal and 13 private domestic wastewater treatment facilities are potential contributors of *E. coli* loading. Currently 18 of the facilities do not disinfect their effluent, however appropriate *E. coli* limits or schedules of compliance are provided in state operating permits.

Table 8. Point Source *E. coli* Load Reduction Strategies

Type	Objective	Strategies
Municipal and domestic wastewater dischargers	Meet wasteload allocations assigned in Section 8.1 of TMDL report	• Appropriate *E. coli* permit limits • Disinfection • Consider no discharges option • Reduce occurrences of sanitary sewer overflows
CAFOs	Meet wasteload allocations assigned in Section 8.3 of the TMDL report	• Maintain no discharge • Land apply waste according to permitted conditions • Nutrient management plans to manage manure application rates
Illicit straight pipe discharges	Illegal discharges and therefore should be eliminated from the watershed	• Report known discharges to local county health departments

7. Nonpoint Source Implementation

7.1 Focus Areas for Nonpoint Source Management

Areas that contribute the highest nonpoint source loading to South Grand River should be prioritized for management practices. Typical focus areas are those where water bodies are adjacent to cropland and pastureland. Nonpoint source management measures that reduce nitrogen and phosphorus loading are also effective *E. coli* reduction measures. The focus areas for nonpoint source management provided in Table 8 and Figure 4 are based on estimated nitrogen loads because *E. coli* data are primarily sampled only near Archie, MO. The relative nutrient loading rates per acre are provided for informational purposes only. Management practices for nonpoint source load reductions will benefit water quality in South Grand River when conducted in any area of the watershed. Landowners and watershed groups seeking Soil and Water Conservation and CWA Section 319 grant funds should prioritize activities based on local interest and potential for success.

Nitrogen and phosphorus loading from each 12-digit hydrologic unit code (HUC-12) watershed in Missouri was estimated using EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL). Land cover, number of animals, and septic sewer system inputs are based on information downloaded

from the STEPL Input Data Server. The input data server currently uses 2011 land use area distribution and 2012 agricultural animal count. Nitrogen loading rates in each HUC-12 watershed range from 5.04 to 8.71 pounds (lbs) per year per acre. Phosphorus loading rates in each HUC-12 watershed range from 0.70 to 1.13 (lbs/year)/acre. Table 8 presents the proportions of nonpoint nitrogen and phosphorous loading to total area in each HUC-12. Ranks based on relative loading are displayed on Figure 4.

Table 9. Estimated Nitrogen and Phosphorus Loading by HUC-12 Watershed

HUC-12	N Load (lbs/year)	P Load (lbs/year)	N load/area (lbs/year)/acre	P load /area (lbs/year)/acre	Relative Loading
102901080101	245,044	31,387	7.47	0.96	High
102901080102	182,709	22,114	7.56	0.91	High
102901080103	147,510	18,061	7.04	0.86	Medium
102901080104	284,958	34,177	7.17	0.86	Medium
102901080105	150,874	18,980	7.01	0.88	Low
102901080201	222,568	27,661	7.60	0.94	High
102901080202	174,782	23,178	7.43	0.99	High
102901080203	243,780	31,832	7.28	0.95	High
102901080204	258,408	32,291	7.18	0.90	Medium
102901080205	164,164	22,009	7.26	0.97	High
102901080301	235,720	31,027	7.29	0.96	High
102901080302	168,058	22,967	6.53	0.89	Low
102901080303	145,144	16,891	6.98	0.81	Low
102901080304	143,372	17,196	7.16	0.86	Medium
102901080305	61,847	7,751	7.04	0.88	Medium
102901080306	201,640	27,093	6.94	0.93	Low
102901080307	113,622	14,121	7.40	0.92	High
102901080308	187,593	27,024	6.95	1.00	Low
102901080309	149,963	19,191	7.24	0.93	Medium
102901080401	157,154	20,003	7.06	0.90	Medium
102901080402	307,583	38,867	7.04	0.89	Medium
102901080403	193,289	24,702	7.11	0.91	Medium
102901080404	209,818	25,641	6.87	0.84	Low
102901080405	102,162	14,277	5.04	0.70	Low
102901080501	240,200	31,283	8.71	1.13	High
102901080502	234,345	30,421	7.20	0.94	Medium
102901080503	257,770	32,705	7.05	0.89	Medium
102901080504	116,722	13,690	7.37	0.86	High
102901080505	198,945	24,783	6.58	0.82	Low
102901080506	235,295	29,631	6.61	0.83	Low
102901080701	137,832	18,433	5.42	0.72	Low
102901080702	104,489	15,327	5.70	0.84	Low

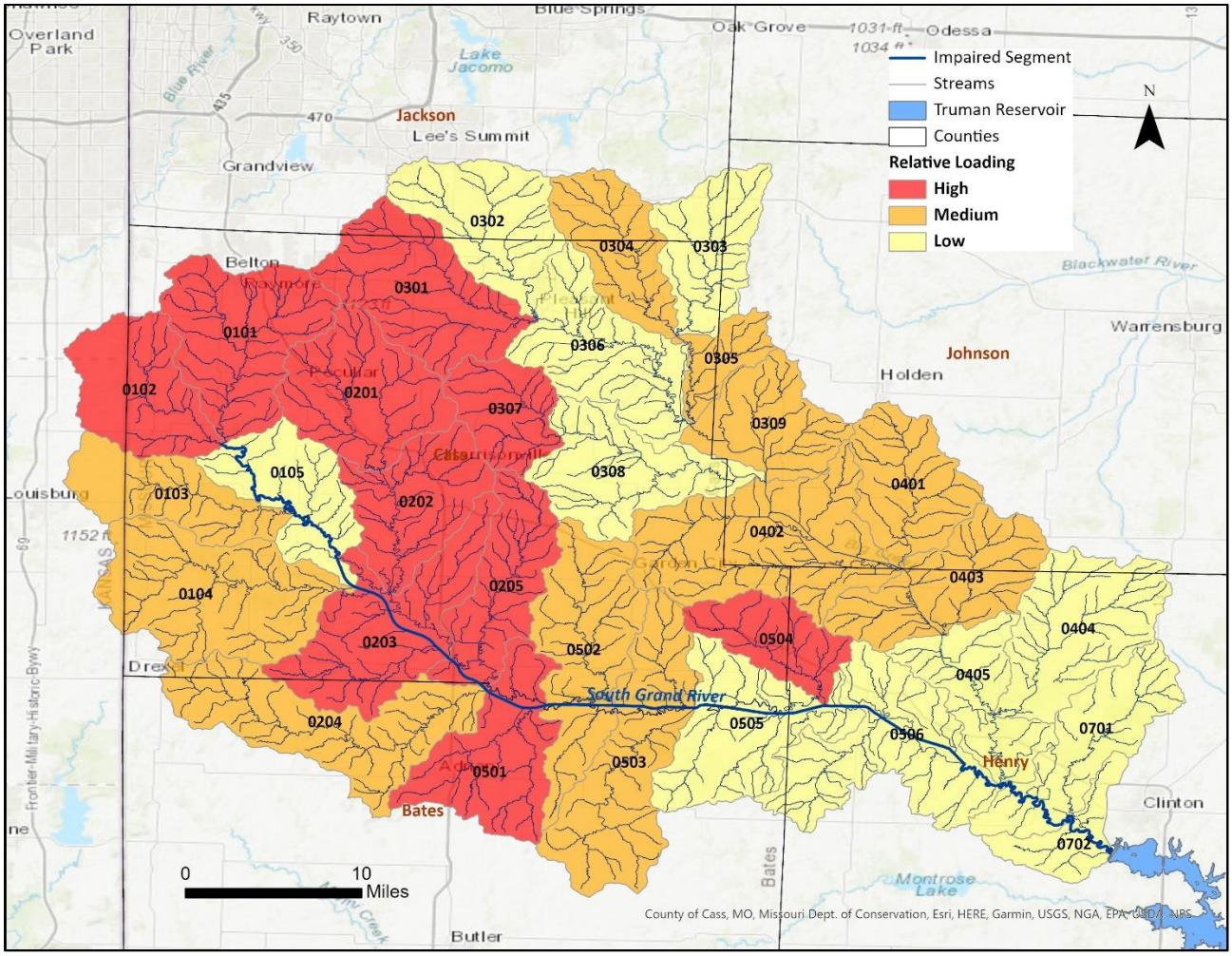

Figure 3. Relative Nitrogen and Phosphorus Loading by HUC-12 Watershed

7.2 Nonpoint Source Management Activities Previously Implemented

The Missouri Soil and Water Conservation Program provides cost-share for a variety of best management practices that support reductions of *E. coli* loading from agricultural lands. Many soil and water conservation management practices that reduce erosion also reduce *E. coli* and nutrient loading. Table 10 summarizes the types of practices implemented in the South Grand Watershed between 2017 and 2021 and the pollutants the practices address.

Table 10. Pollutants Addressed by Specific Soil and Water Conservation Practices

	Pollutants Addressed		
Practice Type	**Sediment**	**Nutrients**	***E. coli***
Permanent Vegetative Cover Establishment	X	X	X
Terrace System	X	X	
Terrace System with Tile	X	X	
Sod Waterway	X	X	
Cover Crop	X	X	X
Erosion Prevention by Water Diversion	X	X	
Grazing System Water Development	X	X	X
Grazing System Water Distribution	X	X	X
Grazing System Fence	X	X	X

Practice Type	Pollutants Addressed		
	Sediment	**Nutrients**	***E. coli***
Water Impoundment Reservoir	X	X	
Sediment Retention, Erosion or Water Control Structure	X	X	
Sod Waterway	X	X	
Livestock Exclusion	X	X	X
Nutrient Management	X	X	X
Stream Protection	X	X	X

Total treatment area and number of total cost-share projects implemented in the South Grand River watershed between 2017 and 2021 are summarized by county in Table 11. The Missouri Soil and Water Conservation Program estimates that a total of 178,888 tons of soil loss will be prevented over the life-span of the 250 total practices that address sediment, nutrient, and *E. coli* loading in 41,582 acres of the South Grand River watershed.

Table 11. Nonpoint Source Management Practices Implemented 2017-2021

County	Type	Total Treatment Acres	Total No. Practices
Bates	Permanent Vegetative Cover Establishment	18.7	1
	Terrace System	37.1	5
	Terrace System with Tile	83.0	6
	Sod Waterway	49.6	1
	Cover Crop	2,491.9	13
	Total	**2,680.3**	**26**
Cass	Permanent Vegetative Cover Establishment	525.8	13
	Terrace System	37.3	3
	Erosion Prevention by Water Diversion	44.6	4
	Terrace System with Tile	467.8	18
	Grazing System Water Development	195.7	3
	Grazing System Water Distribution	294.6	4
	Grazing System Fence	505.6	5
	Water Impoundment Reservoir	178.0	3
	Sediment Retention, Erosion or Water Control Structure	106.0	2
	Sod Waterway	299.1	5
	Cover Crop	10,087.6	31
	Livestock Exclusion	7.2	4
	Nutrient Management	1,241.2	25
	Stream Protection	27.2	5
	Total	**14,017.7**	**127**
Henry	Terrace System	41	2
	Terrace System with Tile	290	11

County	Type	Total Treatment Acres	Total No. Practices
	Grazing System Water Development	150.5	1
	Grazing System Water Distribution	233.2	2
	Sod Waterway	478	6
	Cover Crop	876.2	9
	Nutrient Management	301	2
	Stream Protection	12.1	1
	Total	**2,382**	**34**
Jackson	Permanent Vegetative Cover Establishment	23.6	1
	Terrace System	93.1	4
	Terrace System with Tile	26.5	3
	Water Impoundment Reservoir	48	1
	Sod Waterway	33.5	1
	Cover Crop	1,573.7	10
	Total	**1798.4**	**20**
Johnson	Terrace System	68.3	10
	Terrace System with Tile	498.1	16
	Grazing System Fence	74.7	1
	Sod Waterway	249.3	3
	Cover Crop	1,661.6	14
	Livestock Exclusion	3.0	1
	Total	**2,555**	**45**
2017-2021 South Grand Watershed Total		**41,582**	**250**
Total *E. coli* Treatment Area in Acres		**20,271**	

7.3 Potential Nonpoint Source Management Measures

Nonpoint source management measures should focus primarily on reducing *E. coli* and nutrient loading from cropland and pasture lands because loading is typically higher from these areas. Suggested nonpoint source management measures are summarized in the following sections.

7.3.1 Riparian Buffers

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in erosion reduction, as well as the detention, removal, and assimilation of pollutants in runoff. Therefore, a stream with good riparian cover is better able to mitigate the impacts of high pollutant loads than a stream with poor or no riparian cover. Shade provided by riparian corridors is also important because it helps to keep water cooler (cold water holds more oxygen) and reduces temperature variation that stresses aquatic life especially during the critical low flows that typically occur in July and August. Over 33 percent of the riparian corridors in the South Grand River watershed are covered by either

cropland or pastureland. Riparian corridors that lack woody vegetation should be prioritized for riparian restoration.

7.3.2 Streambank Stabilization

Streambank stabilization measures also reduce erosion. Such measures may include the installation of live stakes, coconut fiber rolls and mesh, coir rolls, bank terracing, large woody debris, and large boulders to support streambanks and reduce erosion. Integrating shrub and tree planting with other bank stabilization measures results in long-term stabilization as the vegetative roots expand and provide further soil stability. Many resources are available to guide streambank stabilization design for specific conditions. A good initial reference is the *Army Corps of Engineers Streambank and Shoreline Protection Manual* (https://www.lrc.usace.army.mil/Portals/36/docs/regulatory/pdf/StrmManual.pdf).

A study of bank stabilization on the Cedar River in Nebraska (Naisargi and Mittelstet 2017) found the average streambank erosion rate before stabilization was approximately 1.5 ft^2/ft and was reduced to 0.5 ft^2/ft after stabilization measures were implemented. [10]

7.3.3 Livestock Exclusion

Livestock that have access to streams reduce streamside vegetation, increase barren areas, and contribute *E. coli* and nutrients directly to streams. In addition, compaction from animals contributes to poor quality aquatic habitat because the interstitial spaces in stream substrate are eliminated. Excluding livestock from streams is another way to improve water quality and aquatic habitat in the South Grand River watershed.

[10] The Cedar River watershed is located in North Central Nebraska. The western half of the watershed is mainly grassland and sand dunes in the Sand Hills, whereas the eastern half is predominantly cropland.

7.3.4 Nutrient Management

Nutrient management is the most effective strategy for reducing *E. coli* and nutrient loading from agricultural lands to streams. The *Missouri Concentrated Animal Feeding Operation Nutrient Management Technical Standard* is available online at: dnr.mo.gov/water/business-industry-other-entities/permits-certification-engineering-fees/concentrated-animal-feeding-operation-permits. The technical standard describes soil and manure testing protocols, manure application criteria including required setback distances from streams, and monitoring requirements. Department staff are available to assist CAFO operators in the development of effective nutrient management plans.

The primary goal of nutrient management is to promote biomass productivity that provides profit for producers while minimizing negative environmental impacts. Over-application of nitrogen and phosphorus above the crop needs will cause these nutrients to accumulate in the soil and increase the potential for losses to the environment. Nutrient management planning minimizes the transport of *E. coli*, nitrogen, and phosphorus to surface and ground water by optimizing fertilizer application rates, timing, and placement, as well as accounting for all sources of nutrients.

Nutrient management plans may be eligible for cost-share programs through the Soil and Water Conservation Program. Nutrient Management Plans should be developed in accordance with the Natural Resources Conservation Service Standards and Specifications for Nutrient Management (590). Landowner assistance is available through the Newton and McDonald County Soil and Water Conservation Districts.

In general, the following are required to begin nutrient management planning:

- Soil samples, based on a 7-inch depth, shall be taken once every 4 years, as a minimum, to monitor the phosphorus, potassium, pH and organic matter levels and adjust nutrient application rates as needed. The pH of the soil is important because it has a direct effect on nutrient availability. Follow Iowa State University recommendations and soil testing procedures to develop a crop budget for determining crop nutrient needs. Nitrate testing using the late spring nitrate test and fall corn stalk test can be used to monitor the nitrogen management program. Soil pH levels shall be maintained near 6.5 for corn and soybeans and 6.9 for alfalfa.
- Manure analysis could be completed on an annual basis for percent of solids, total nitrogen, organic nitrogen, ammonium, phosphorus, potassium and pH. A more realistic nutrient content can be obtained by using the averages of three or more analysis.
- Soil tests and realistic yield potentials will be used to determine the application rate of manure so as to supply most of the crop nutrient needs through the manure and legume credits. No additional commercial phosphate or potash will be applied on soils testing high or very high in phosphorus and potassium (K). On these fields additional commercial nitrogen will be applied as needed. This will optimize crop yield potential while minimizing nutrient runoff and nitrogen leaching.
- Sensitive areas: Commercial nutrients, manure and organic by-products shall not be applied to frozen, snow covered ground or saturated soil on slopes greater than five percent unless erosion is

controlled. Manure and organic by-products shall not be applied within 200 ft. of a stream, lake, agricultural drainage well, or sinkhole unless injected or incorporated within 24 hours.

- Risk Analysis: The phosphorus index will be used to determine fields that are a high risk for phosphorus losses. Conservation and/or management practices will be used to reduce the potential for phosphorus movement off site. Soil tests will be taken every four years to determine changes in phosphorus levels.

The plan should receive periodic review to determine if adjustments or modifications are needed. At a minimum the plan will be reviewed and revised with each soil test cycle.

7.3.5 Cover Crops

Planting cover crops rather than leaving cultivated cropland barren has both economic and environmental benefits. Legume cover crops can reduce fertilizer costs because they contribute nitrogen to soils. Legumes such as vetch and clover convert nitrogen gas from the atmosphere into soil nitrogen that crops can use. This reduces the amount of fertilizer that needs to be purchased and applied. Applying less fertilizer to the topsoil means reduced transport of nutrients to water bodies in the watershed. Cover crops also reduce erosion by holding soil in place and reducing top-soil crusting. The plant material left behind after cover-cropping increases water infiltration and reduces evaporation. This reduces the amount of nutrient-laden runoff, and the amount of water needed for irrigation. Moisture retention by decaying plant material also helps soils be more resilient to periodic drought conditions.

A study conducted by Zhu et al. (1989) as cited in Sharpley and Smith (1991) found that planting common chickweed, Canada bluegrass, and downy brome on Missouri soybean fields decreased water runoff by an average 44 percent. The study found that nitrogen (as nitrate) loss was reduced by an average 75 percent and soluble phosphorus runoff was reduced by an average 37 percent. Sharpley and Smith (1991) found that planting ryegrass or wheat on peanut crops for 6 months of the year reduced soil loss by an average of 83 percent.

The Missouri Parks, Soils, and Water sales tax program provides grants to cover up to 75 percent of the cost of planting cover crops, alternative crops, and vegetative buffer zones (field borders). The grants are administered through the Missouri Soil and Water Conservation Program.

7.3.6 Prairie Strips

Integrating prairie strips in croplands can reduce both soil erosion and nutrient runoff. Prairie strips include edge of field filter strips and infield contour buffer strips. Infield contour buffer strips' primary purpose is to reduce erosion, while edge of the field filter strips primary purpose is to filter excess nutrients and animal waste. A study conducted in Iowa found that converting 10 percent of crop field to prairie filter strips reduced mean annual nitrate, total nitrogen, and total phosphorous concentrations in receiving waters by 35, 73, and 82 percent respectively (Zhou et al. 2014). Grants provided by the Missouri Parks, Soils, and Water sales tax program can cover up to 75 percent of the cost of implementing prairie strips.

7.3.7 Field Borders

Field borders can provide a number of conservation benefits, such as reducing soil erosion from wind and water, protecting soil and water quality and providing habitat for wildlife. These habitats, located at the edges of crop fields, can also serve to connect other buffer practices and habitats within the agricultural landscape. The U.S. Department of Agriculture's Farm Service Agency (FSA) runs a program called the Continuous Sign-up Conservation Reserve Program (CCRP) that provides farmers with rental payments on land set-aside for conservation buffers for a period of 10-15 years. Cost-share payments are also made available to help farmers with the financial burden of establishing the buffers.

8. Public Outreach

Public outreach is a key component of any watershed management plan. Measures to reduce pollutant loading from unregulated nonpoint source areas are implemented voluntarily through cooperation between citizen groups, landowners, government agencies, and funding entities. Support for nonpoint source reduction plans is generated through education and outreach activities designed to inform the public about water quality issues and what can be done to reduce pollutant loading in watersheds. The U.S. Environmental Protection Agency, U.S. Department of Agriculture, Natural Resources Conservation Service, Soil and Water Conservation Districts, Missouri Department of Natural Resources, Missouri Department of Conservation, University of Missouri Extension, and local governments produce educational materials and make them available on their websites. Staff within these agencies are available to assist with public education and provide technical support for watershed plan development.

The following are some activities recommended to develop support and participation for watershed stewardship.

1. Hold meetings and other outreach events to inform private landowners of the available technical support and financial incentives for implementing pollutant reduction strategies.
2. Attend livestock auctions and demonstrations in the local community, and hand-out literature explaining the available technical support and financial incentives for implementing pollutant reduction strategies.
3. Develop small-scale demonstrations of pollutant reduction strategies.
4. Implement a public awareness campaign regarding water quality with public service announcements.
5. Host local watershed festivals.

9. Measurable Milestones

Measurable milestones outline time frames for the incremental implementation of pollutant reduction strategies. Attainable milestones should be established based on available funding and stakeholder participation. For point sources, milestones may be integrated into permits as schedules of compliance to allow time to plan, fund, and construct facility upgrades or implement adaptive management. Nonpoint source pollutant reduction plans should include milestones for public outreach, attaining funding, and the implementation of chosen nonpoint source management measures. In addition, monitoring and adaptive management plans should be developed for vegetation restoration areas to ensure that plants are healthy and will grow and develop into effective *E. coli* and nutrient attenuation areas. Plans that are developed to procure Section 319 subgrants must be renewed every five years in order to stay eligible for funding. It is good general practice to develop measurable watershed management milestones on 5-year timeframes. Riparian buffer restoration monitoring and adaptive management plans should include annual monitoring and assessment of plant growth and development with a 5 to 7-year goal of vegetation maturity. The annual evaluations allow for adaptive management to ensure that efforts are successful.

10. Cost-Benefit

Cost-benefit analyses should be conducted during the watershed management planning process to determine the most efficient investments of time, effort, and supplies. Upgrades to point source facilities should consider both the immediate and necessary future capacity of the facility and should be designed based on the best available affordable technology. Costs associated with nutrient management plan implementation and cover crops are relatively minimal because many of the practices are already integrated into the farming system and substantial cost savings are achieved through reducing the need for manure application and chemical fertilizers. Streambank stabilization is the most expensive pollutant reduction strategy but can be limited to key areas to stabilize highly erosive streambanks for the benefit of water quality in all downstream waters.

11. Cooperating Agencies and Funding Sources

Reducing pollutant loading to achieve TMDLs often requires participation and cooperation from government agencies. TMDLs are written to meet applicable water quality standards per federal regulations at 40 CFR 130.7(c)(1). As a result, they are developed without considering citizen interest, available treatment technologies, or costs associated with nonpoint source management measures. Public service staff can assist with outreach and education, provide technical guidance, and direct interested parties to potential funding sources. Some of the available agencies and organizations and their potential roles, including funding avenues, are listed in Table 11. The list is

not exhaustive and not intended to compel participation from any organization nor is it meant to exclude any who are not listed, but gives a general idea of responsibilities and potential roles in watershed management. The most commonly used sources of funding are low-interest loans through the State Revolving Fund, Section 319 subgrants, and cost-share practices through the state's Soil and Water Conservation Program.

Table 12. Agency Roles and Funding Options

Agency and Roles	Funding Options
US Department of Agriculture, Natural Resources Conservation Service https://www.nrcs.usda.gov/wps/portal/nrcs/site/mo/home/	
Financial assistance and incentives to implement voluntary best management practices (BMPs)	Environmental Quality Incentives Program (EQIP) Regional Conservation Partnership Program (RCPP) Conservation Stewardship Program (CSP) Agricultural Conservation Easement Program (ACEP)
US Department of Agriculture's Farm Service Agency (FSA) https://www.fsa.usda.gov/	
Administers a program called the Continuous Sign-up Conservation Reserve Program (CCRP) that provides farmers with rental payments on land set-aside for conservation buffers for a period of 10-15 years. Cost-share payments are also made available to help farmers with the financial burden of establishing the buffers.	Continuous Sign-up Conservation Reserve Program (CCRP)
Missouri Department of Natural Resources dnr.mo.gov/	
Water Protection Program (phone: 573-751-5723) Implements federal Clean Water Act regulations including: enforcing National Pollutant Discharge Elimination System (NPDES) regulations through point source facility operation permits, establishing Water Quality Standards, identifying impaired water bodies, and developing TMDLs.	Free volunteer water quality monitoring training and tools
Financial Assistance Center dnr.mo.gov/water/business-industry-other-entities/financial-opportunities/financial-assistance-center Provides technical guidance for publicly-owned treatment works and administers low-interest long-term loans to assist with technology and capacity upgrades. The Clean Water State Revolving Fund provides subsidized loans to municipalities, counties, public sewer districts, and political subdivisions for wastewater infrastructure projects. Loans may be paired with grant funds for qualifying communities. Eligible projects include new construction or improvement of existing facilities.	Clean Water State Revolving Fund

Agency and Roles	Funding Options
Soil and Water Conservation Program dnr.mo.gov/land-geology/soil-water-conservation The Soil and Water Conservation Program (SWCP) provides financial incentives to landowners to implement practices that help prevent soil erosion and protect water quality. The program offers cost-share for a range of best management practices through its county conservation districts. Landowners may receive up to 75 percent reimbursement of the estimated cost of a practice through the program. The primary funding for cost-share practices from the Soil and Water Conservation Program comes from the one-tenth-of-one percent Parks, Soils, and Water Sales Tax.	SWCP cost-share
Section 319 Nonpoint Source Program dnr.mo.gov/water/what-were-doing/nonpoint-source-pollution-section-319 ▪ Provides Section 319 subgrants for the development of watershed management plans and implementation of practices listed in approved plans.	Section 319 subgrants
Missouri Department of Conservation https://mdc.mo.gov/	
Provides outreach, education, and technical guidance for stream and watershed management issues. Maintains Missouri Conservation lands. Issues permits for fishing and hunting.	Free volunteer water quality monitoring training and tools
Missouri Agricultural and Small Business Development Authority agriculture.mo.gov/abd/financial/awloanprg.php	
Offers an Animal Waste Treatment System Loan Program in cooperation with the Clean Water State Revolving Fund. Animal Waste Treatment Loans Program may finance eligible animal waste treatment systems for independent livestock and poultry producers with operations of less than 1,000 animals. Eligible costs include storage structures, land, dedicated equipment, flush systems, composters, and more.	Clean Water State Revolving Fund
University of Missouri Extension https://extension2.missouri.edu/	
Provides guidance for farm management including crop resilience, pond health, and livestock care.	Free information and assistance
County Soil and Water Conservation Districts https://mosoilandwater.land/	

Agency and Roles	Funding Options
Provides guidance and assistance with the development of nutrient management plans and procurement of funding from the state cost-share program.	Free information and assistance with grant applications
Online Databases of Additional Funding Sources	
▪ Wichita State University, Environmental Finance Center (EFC) Missouri Healthy Watershed Funding Search Tool https://www.wichita.edu/academics/fairmount_college_of_liberal_arts_and_sciences/hugowall/efc/news/meramec-funding-sources-landing-page.php ▪ Catalog of Federal Funding https://www.epa.gov/waterdata/catalog-federal-funding ▪ EPA Nonpoint Source Funding Opportunities http://water.epa.gov/polwaste/nps/funding.cfm ▪ Environmental Justice Grants https://www.epa.gov/environmentaljustice/environmental-justice-grants-and-resources ▪ Grants.gov http://www.grants.gov	

12. Conclusion

The ultimate goal of pollutant reduction strategies is to meet Missouri Water Quality Standards through the protection of aquatic life in warm water habitats and whole-body contact recreation. Implementation strategies should follow an adaptive approach that makes progress toward achieving water quality goals while using new data and information to reduce uncertainty and adjust implementation activities. Implementation efforts are expected to occur over a number of years, but within the schedules established in state operating permits and watershed management plans. Success in achieving water quality standards will be determined by the Department through biennial assessments of water quality compliance as required by Sections 305(b) and 303(d) of the federal Clean Water Act.

The Department maintains administrative records for the South Grand River TMDL. The records contain the TMDL document, this implementation strategies document, and any studies, data, or calculations upon which loading targets are based. This information is available upon request to the Department at dnr.mo.gov/open-records-sunshine-law-requests. Any request for information about TMDLs will be processed in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the Department's administrative policies and procedures governing Sunshine Law requests.

This implementation strategies document is scheduled for a 45-day public notice and comment period in conjunction with the comment period for the South Grand River *E. coli* TMDL. Any comments received, as well as the Department's responses to those comments, will be maintained on file with the Department and posted online at dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/tmdls. The Department maintains an email distribution list for notifying subscribers of significant TMDL updates or activities. Those interested in subscribing to these TMDL updates can submit their email address using the online form at public.govdelivery.com/accounts/MODNR/subscriber/new?topic_id=MODNR_177.

13. References

Federal Geographic Data Committee (FGDC). 2003. FGDC Proposal, Version 1.1, Federal Standards for Delineation of Hydrologic Unit Boundaries. December 23, 2003.

Guber, A. K., Shelton, D. R., Pachepsky, Y. A., Sadeghi, A. M., & Sikora, L. J. (2006). Rainfall-induced release of fecal coliforms and other manure constituents: comparison and modeling. *Applied and Environmental Microbiology*, *72*(12), 7531-7539.

MoRAP (Missouri Resource Assessment Partnership). 2005. A gap analysis for riverine ecosystems of Missouri. Final report, submitted to the USGS national gap analysis program. 1675pp.

Naisargi, Dave and Mittelstet, Aaron, R. 2017. Quantifying Effectiveness of Streambank Stabilization Practices on Cedar River, Nebraska. *Water* 9:930. doi:10.3390/w9120930.

NRCS (Natural Resources Conservation Service). 2013. Nutrient Management Plan Narrative with Livestock. [Online WWW] Available URL: https://nerc.org › documents › comprehensive_nutrient_management [Accessed 2021].

Sharpley, A.N. and Smith, S.J. 1991. Effects of cover crops on surface water quality. *Surface Water Impacts.* Available URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.596.3210&rep=rep1&type=pdf [Accessed February 2021].

Sutton, Alan L. 1990. Animal Agriculture's Effect on Water Quality Pastures and Feedlots. WQ-7. Purdue University Extension. [Online WWW]. Available URL: http://www.ces.purdue.edu/extmedia/wq/wq-7.htmL [Accessed 23 Dec. 2011].

Zhou, X., Helmers, M. J., Asbjornsen, H., Kolka, R., Tomer, M. D., & Cruse, R. M. 2014. Nutrient removal by prairie filter strips in agricultural landscapes. *Journal of Soil and Water Conservation*, *69*(1), 54-64.

Zhu, J.C., Gantzer, C.J., Anderson, S.H., Alberts E.E., and Beuselinck, P.R. 1989. Runoff, soil, and dissolved nutrient losses from no-till soybean with winter cover crops. *Soil Science Society of America Journal.* 53:1210-1214.

USDA-SCS 1993. Missouri watershed progress summary 1993.United States Department of Agriculture, Soil Conservation Service. Columbia, MO. 68 pp.

Appendix A
Nine Key Elements Critical to a Watershed Management Plan

a. An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan, as discussed in item (b) immediately below. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).

b. An estimate of the load reductions expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as in item (a) above (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded streambanks).

c. A description of the nonpoint source management measures that will need to be implemented to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

d. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, U.S. Department of Agriculture's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds that may be available to assist in implementing this plan.

e. An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

f. A schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

g. A description of interim, measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

h. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a nonpoint source TMDL has been established, whether the nonpoint source TMDL needs to be revised.

i. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

Appendix B
Targeted Participants and Potential Roles in Implementation

The Department implements TMDL targets for point sources through the Missouri State Operating Permit program. For nonpoint sources, private landowners and citizen groups voluntarily implement water quality improvement projects and cost-share practices, which may be funded in part by grants or subgrants from the Department's Section 319 Nonpoint Source Implementation Program and the Soil and Water Conservation Program. Local governments, citizen groups, and individuals who have an interest in improving water quality in their communities may implement additional water quality improvement actions. Successfully meeting the goals of a TMDL often requires participation and cooperation from various parties within a watershed. Participant roles range from technical support to actual on-the-ground implementation of BMPs. Groups and agencies that may potentially be involved in the TMDL implementation process are identified below along with descriptions of their possible roles. This list is not exhaustive and not intended to compel participation from any organizations; nor is it meant to exclude those who are not listed, but may be interested in participating.

- Department of Natural Resources
    - Administers statutory authorities granted by Missouri clean water law
    - Ensures permits issued in the watershed are consistent with the assumptions and requirements of TMDL wasteload allocations (the allowable point source load)
    - Provides compliance assistance to regulated entities
    - Provides technical support to locally-led watershed groups
    - Serves as a potential source of financial assistance for watershed plan development and BMP implementation through Sections 319(h) and 604(b) grants, or through Soil and Water Program cost-share practices
    - Serves as a potential source of financial assistance for infrastructure improvements through low-interest State Revolving Fund loans
    - Assesses attainment of water quality standards on a biennial basis for Clean Water Act Sections 303(d) and 305(b) reporting Implementation Strategies for South Grand River
    - Provides education and training to volunteers through the Missouri Stream Team Program
    - Provides technical assistance for market-based approaches to compliance such as water quality trading
- County Soil and Water Conservation Districts
    - Provide financial incentives to agricultural producers to implement conservation practices that help prevent soil erosion and protect water quality
    - Provide technical assistance with design, implementation, and maintenance of conservation practices
- University of Missouri Extension
    - Provides technical assistance for addressing nonpoint source and watershed management issues
    - Assists with organizing locally led watershed groups
- Missouri Department of Conservation o Provides technical assistance with stream and watershed management issues
    - Promotes maintenance and reestablishment of stable streambanks and functional riparian corridors

- Missouri Department of Health and Senior Services
    - Provides technical assistance pertaining to onsite wastewater treatment systems (i.e., septic)
- County Health Departments
    - Provide technical assistance pertaining to onsite wastewater treatment systems
- Wastewater Treatment Facilities
    - Operate in accordance with stated permit limits, conditions and schedules
    - May participate in water quality trading implementation
- Municipal Separate Storm Sewer Systems
    - Operate in accordance with stated permit conditions and schedules
    - May participate in water quality trading implementation
- Locally led watershed groups
    - Develop and implement Section 319-funded nine key element watershed-based plans.6 (See Appendix A)
    - Identify critical areas at a local level
    - Implement BMPs to reduce nonpoint source pollutant loading
    - Provide public education and outreach
- Stream Team volunteers
    - Collect screening level water quality data (i.e., dissolved oxygen and biological monitoring) through the Volunteer Water Quality Monitoring program
    - Provide stewardship, advocacy, and education.